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Domain Walls in Random Field Ising Magnets: Wetting

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Abstract

Domain walls in random-field Ising magnets can be investigated in groundstates into which walls are induced by prepared boundary conditions. We outline recent progress, and new results on (domain wall) wetting in random field systems. This is studied in fixed disorder configurations in the presence of an external field, which is varied.

Key words: Random field Ising model, Domain walls, Wetting, Quenched randomness
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The random field Ising model (RFIM) is an example of two competing mechanisms: the local spin couplings favor ferromagnetism (FM) while variations in the random fields favor disorder. In two dimensions (2D) Aizenman and Wehr proved the breakdown of long-range FM order in then groundstates [1], while the three-dimensional case is still studied intensively [2,3]. The nature of the thermodynamic state reflects the domain wall (DW) properties: in the FM state the domains are "stiff", *i.e.,* they have an extensive DW energy.

Such properties can be studied by exact numerical computations by mapping the finding of the RFIM groundstate (GS) into a well-known optimization problem [4]. Domain walls are achieved by imposing suitable opposing boundary conditions. Recent calculations have affirmed in 2D the logarithmic correction to the DW energy and the asymptotically paramagnetic (PM) GS character [5,6]. The domain walls in the effective FM are not strictly self-affine, and *e.g.* the roughness has an exponent of $\zeta \simeq 1.2$. Respectively, the energy fluctuations (GS energy distribution width) do not obey the expected exponent relation $\theta = 2\zeta + d - 3$ for self-affine DWs or directed polymers with RF disorder [7,8].

The implications of the exponents extend beyond comparisons or tests of analytical theories, to *e.g.* how the roughness behavior of DW's manifests in the *wetting* of random field magnets. The mean-field theory for random systems, by Lipowsky and Fisher [9], relates the mean height of the domain wall $\overline{z}$ to the external, binding, field H via $\overline{z} \sim H^{-\psi}$, where $\psi = (2-\zeta)/\zeta$.

Here we present exact numerical simulations with an imposed DW and an external field H. Figs. 1(a) and 1(b) illustrate how the wetting takes place with fixed disorder as H is varied (the

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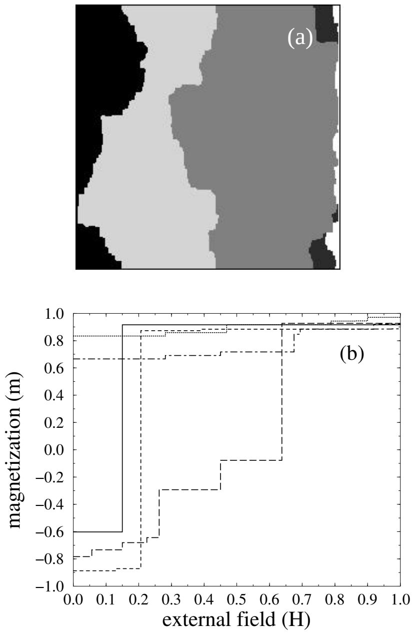

Fig. 1. (a) Examples of successive DW configurations ($\Delta = 0.5$). Different gray colors denote "up" domains at different H values. (b) Magnetization of the full system depending on the mean height $\overline{z}$ vs. the external field H with $\Delta = 0.3$ for 5 different random configurations. The system size $L^2 = 240^2$ and Gaussian disorder (width Δ).

systems are effectively FM). The "dynamics" consists of jumps of various sizes, even macroscopic ones, like in random-bond wetting [10]. This follows from level-crossing. The Hamiltonian has a piecewise continuous derivative w.r.t. H in each disorder configuration.

The effective value of ζ can be now figured out from ψ. If e.g. $\zeta = 1 \Rightarrow \psi = 1$. For $\zeta = 1.2 \Rightarrow \psi = 1.5$. Fig. 2 shows both the interface and roughness behavior with $\psi = 1.5$. Thus the roughness exponent from wetting agrees with earlier direct DW computations.

To summarize, combinatorial optimization is particularly useful for the studies of DW's. The effective $\zeta > 1$, manifesting the super-rough behavior of DW's here and the break-down of true scale invariance, hints about the character of the competition between elastic energy and random field fluctuations, for example in the 3D case.

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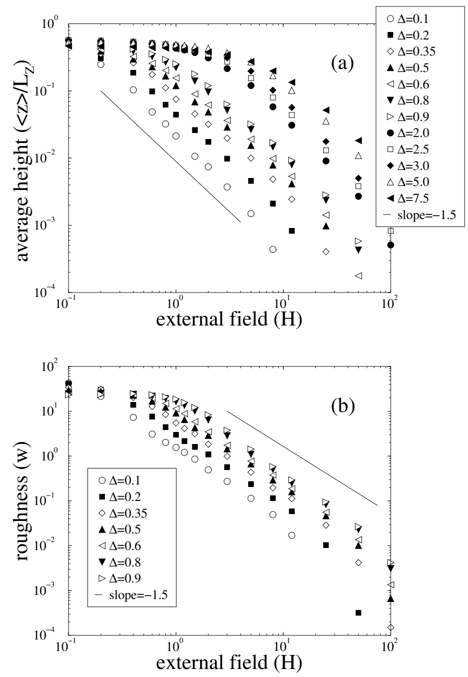

Fig. 2. The scaling of the disorder-averaged interface distance, indicating the value of ψ and the interface roughness, (a): $L^2 = 180^2$ (b): $L_z = 200$, $L = 1000$.

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